Accounting for Water Resources at Catchment Scale
Understanding the Role of Ecosystems

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Centre for Water Resources Research

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SANBI
Biodiversity for Life
South African National Biodiversity Institute

Statistics South Africa
Environment, Forestry and Fisheries
Water and Sanitation
Science and Innovation

Water Research Commission

gef

Water Resources in South Africa

Rainfall (464 mm) ± half global average

50% of runoff from 8% of area

Dam storage is 60% of MAR

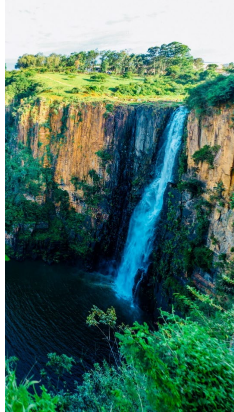
- Scarce and limiting resource
- Spatial and temporal variability
- Highly developed infrastructure
- Land cover change impacts
- Climate change impacts
- International obligations
- Water law recognises IWRM

Climate change: Drier in west

Shared rivers with 6 countries

Land cover change: cultivation, urbanization, degradation, alien invasive plants

“.. the need for the integrated management of all aspects of water resources” NWA Act 36 of 1998

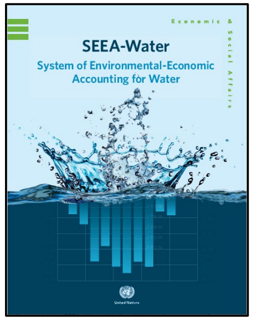


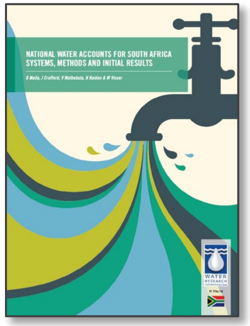
Water Related Accounts in South Africa

National Water Accounts

Stats SA (2002, 2004, 2005, 2006, 2009, 2010)

WRC (2018)

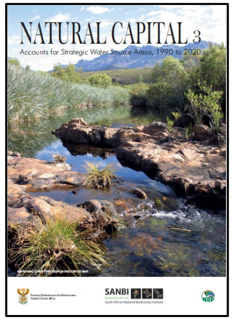




Accounts for SWSAs (Strategic Water Source Areas)

Land and protected area accounts

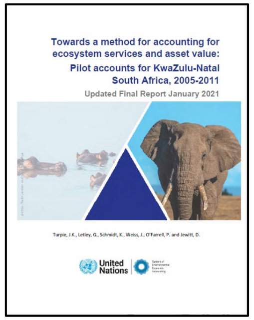
Stats SA, SANBI, DFFE (2023)



Ecosystem service accounts for KZN

Selected water regulating services

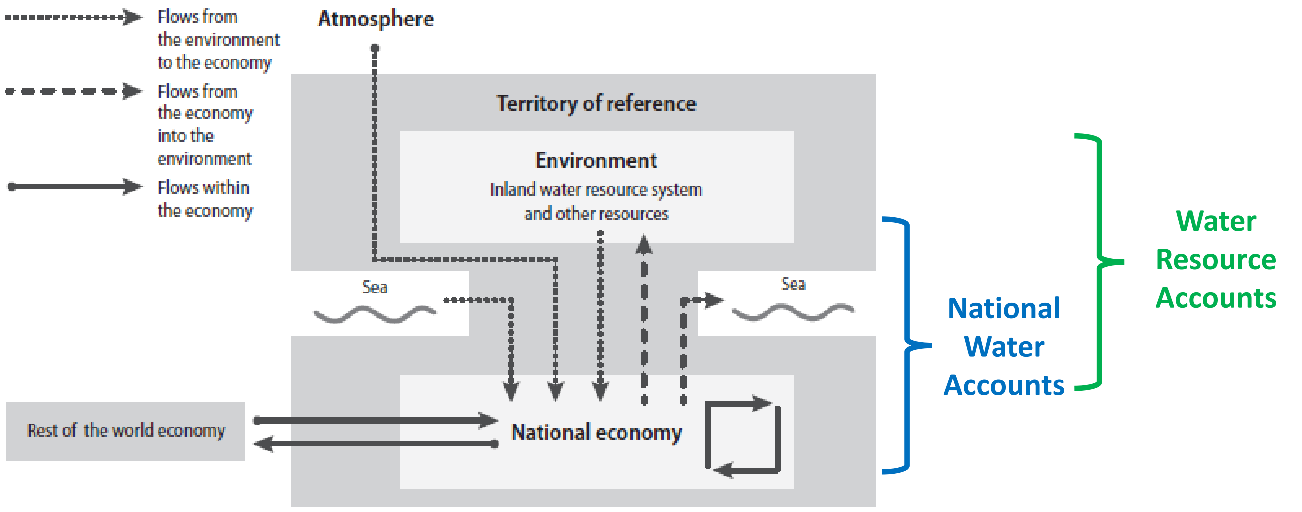
UNEP, UNSD, SANBI, Stats SA (2021)



Why Water Resource Accounts?

National Water Accounts

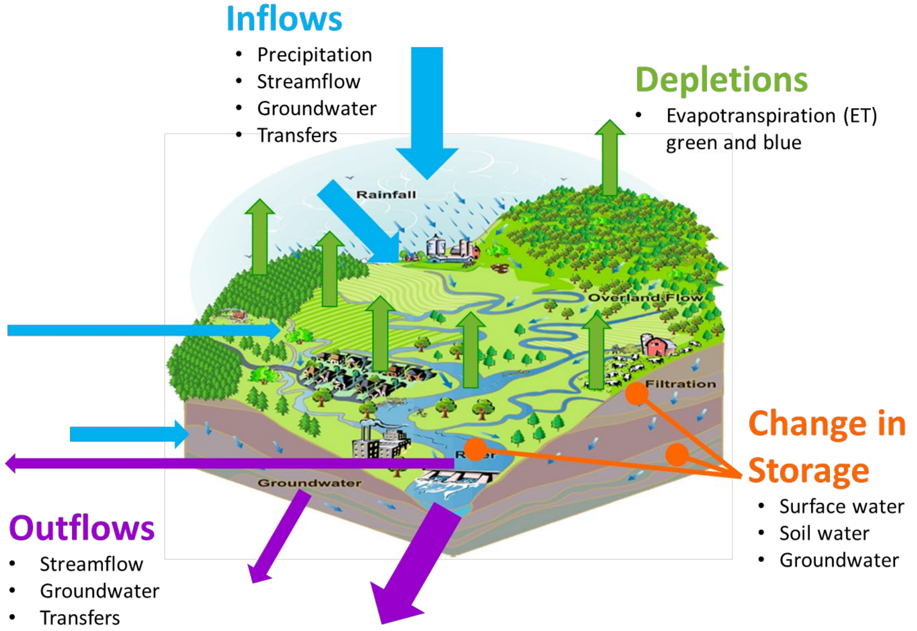
- SEEA-Water
- National and sub-national
- Administrative areas
- Economics emphasis



SEEA-Water (UN, 2012)

Water Resource Accounts

- Physical accounts at finer scale
- Holistic landscape view of water
- Inform land and water management decisions
- Catchments (range of scales)
- Complement National Water Accounts
- Interlinkages with other NCA (land, ecosystems)
- Modelling approach with national datasets



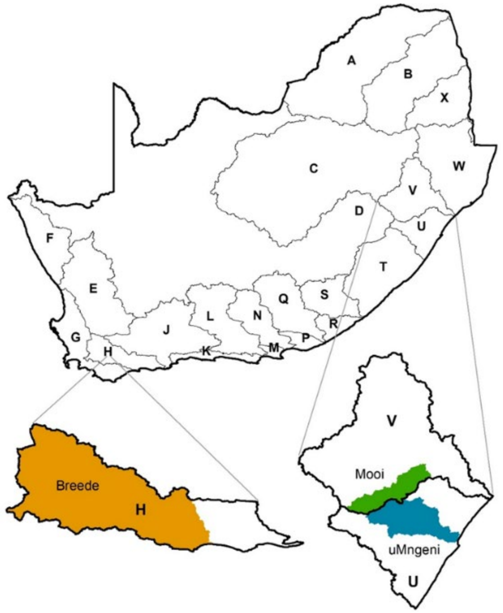
Water Resource Accounts - Development

Development of a methodology

- 2013 – 2019
- CWRR at UKZN
- Based on Water Accounting Plus (WA+)
- National datasets
- Niche between SEEA-Water and WA+

Further development and interlinkages

- 2018 – 2023
- CWRR, SANBI, StatsSA – EI4WS project
- Interlinkages with other NCA
- Case study catchments

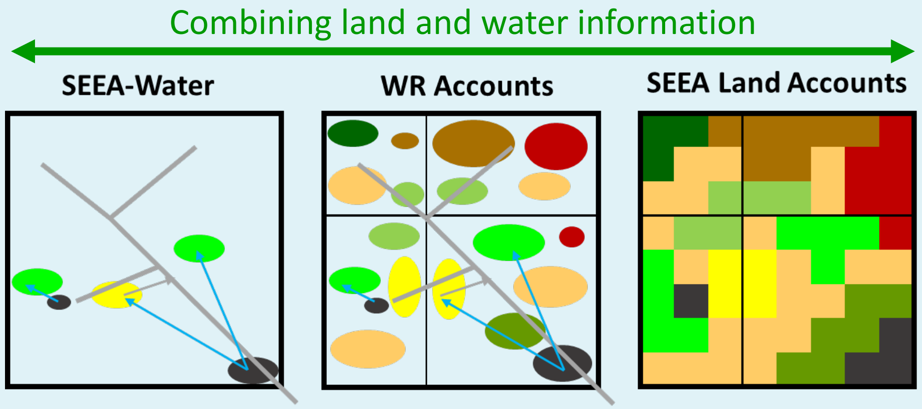


Enabling Interlinkages With Other NCA

Interlinkages – requires some alignment of methods and scope

Common basic spatial unit (BSU)

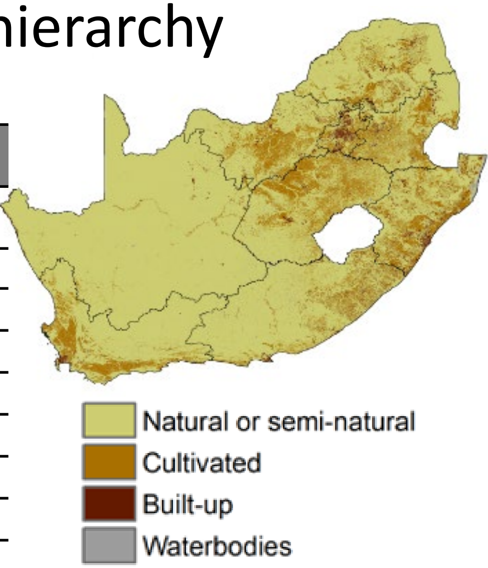
- *"…consistent spatial framework for integrating data"* (Stats SA, 2020)
- 1 ha grid (100 m x 100 m) for SA + EEZ
- Land, ecosystem and water resource accounts
- 20 m national land cover dataset
- Hydrological response units



Land cover classes and hierarchy

- National land cover
  - 20 m
  - 73 classes
  - 2018 – 2020 – (every 2 years)
- National Vegetation Map
- Dam extents
- Common classes - 4-tier hierarchy

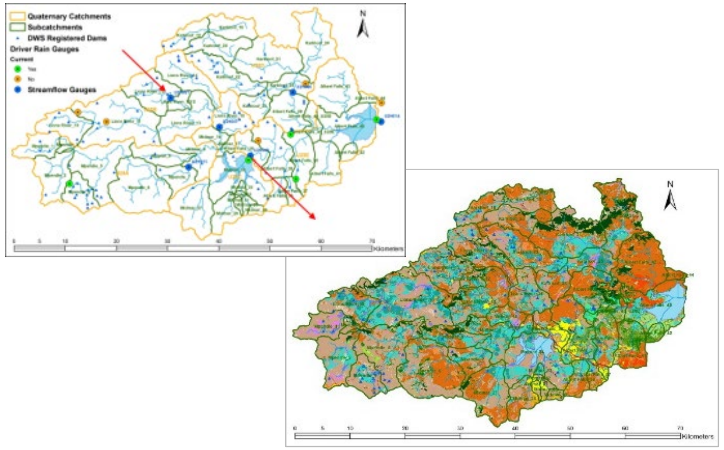
Broad classes	Main cover classes	Detailed classes	NLC classes
Tier 1: 4 classes	*Tier 2: 8 classes*	Tier 3: 19 classes	Tier 4: 73 classes
Natural or semi-natural	Natural or semi-natural	1 class	21 classes
Cultivated	Commercial field crops	4 classes	7 classes
	Subsistence crops	1 class	1 class
	Orchards and vines	2 classes	2 classes
	Timber plantations	1 class	3 classes
Built-up	Urban	7 classes	22 classes
	Mines	1 class	5 classes
Waterbodies	Waterbodies	2 classes	12 classes



Data and the Modelling Approach

Data

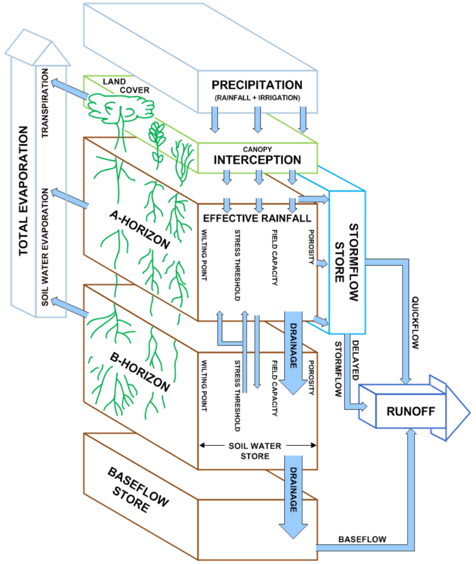
- Accounts are data intensive
- Not feasible to measure everything everywhere
- Fortunate to have several good national datasets



- Topograpy
- Climate
- Land cover/use
- Soils
- Dams
- Population
- Transfers

Deterministic Modelling

- Model ungauged catchments
- Evaluate what-if scenarios (e.g. land cover change)



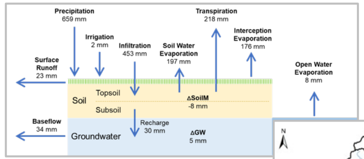
- Infiltration
- Evaporation
- Runoff
- Recharge
- Baseflow
- Streamflow
- Crop requirements

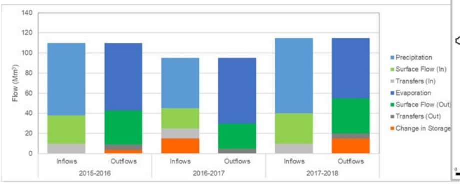
Accounts and Indicators

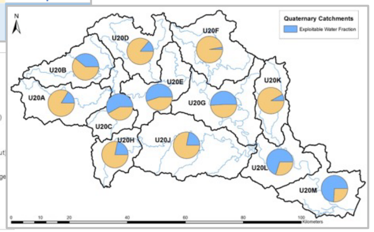
Example Catchment	Depth [mm]					
Area = 2000.0 km^2	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Total In	926.7	819.2	1125.8	878.4	979.4	1072.3
Precipitation	900.0	800.0	1100.0	850.0	950.0	1050.0
Inflows	26.7	19.2	25.8	28.4	29.4	22.3
$Q_{in\ SW}$	0.0	0.0	0.0	0.0	0.0	0.0
$Q_{in\ GW}$	-	-	-	-	-	-
$Q_{in\ Transfers}$	26.7	19.2	25.8	28.4	29.4	22.3
Total Out	835.5	801.8	1042.0	842.7	913.6	974.3
Total Evaporation (ET)	731.0	646.6	818.3	683.2	753.9	776.8
Landscape ET	716.1	632.7	803.3	668.2	739.5	764.0
Incremental ET	14.9	13.9	15.0	15.0	14.4	12.8
Outflows	104.5	155.2	223.7	159.5	159.7	197.5
$Q_{out\ SW}$	76.1	128.8	194.5	130.5	129.7	168.0
$Q_{out\ GW}$	-	-	-	-	-	-
$Q_{out\ Transfers}$	28.4	26.4	29.2	29.0	30.0	29.5
Accessibility: Reserved outflows	28.4	26.4	29.2	29.0	30.0	29.5
Accessibility: Utilizable outflow	76.1	128.8	194.5	130.5	129.7	168.0
Total Change in Storage	-91.2	-17.4	-83.9	-35.7	-65.9	-98.0
$DS_{f\ SW}$	-66.5	-41.3	-70.6	-52.2	-58.2	-71.6
$DS_{f\ SoilM}$	-23.5	22.9	-9.1	8.5	-7.1	-24.7
$DS_{f\ GW}$	-1.2	1.0	-4.2	8.0	-0.6	-1.7

Example Catchment	Depth [mm]					
Area = 2000.0 km^2	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Total Demand	30.9	28.6	30.8	31.0	30.3	28.1
Total Withdrawal	30.5	28.3	30.6	30.3	30.0	28.0
Cultivated	2.7	2.6	3.1	3.0	2.1	1.8
Built-up	27.9	25.6	27.5	27.3	27.9	26.2
Total Consumed	12.2	11.4	12.3	12.3	11.8	10.6
Cultivated	1.6	1.7	2.0	2.0	1.3	1.0
Built-up	10.6	9.7	10.3	10.3	10.6	9.6
Total Returned	15.1	13.9	15.1	14.8	15.1	14.6
Cultivated	-	-	-	-	-	-
Built-up	15.1	13.9	15.1	14.8	15.1	14.6
Deficit	0.3	0.3	0.2	0.7	0.3	0.1

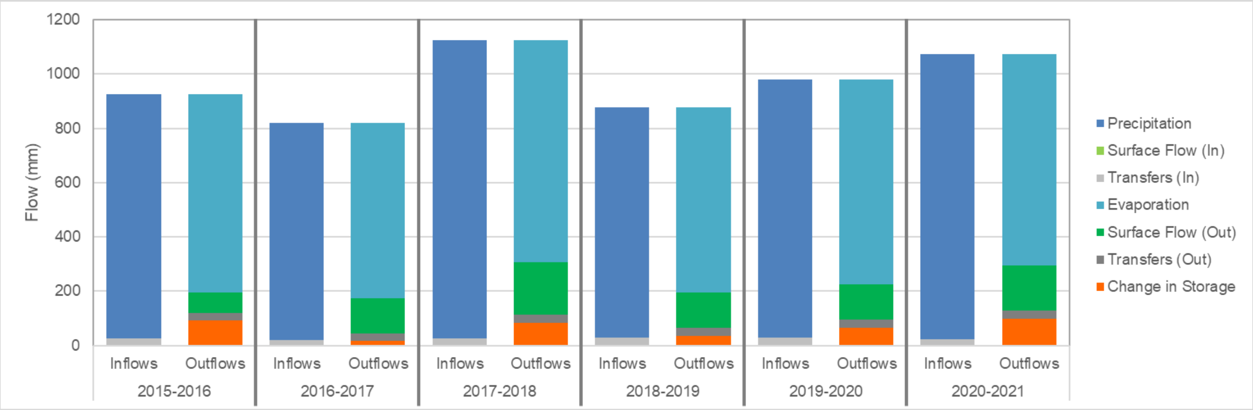
Visualisation







Main Catchment Flows – Temporal Context



Similar to SEEA-Water asset accounts

- Increases, decreases, change
- No opening and closing stocks

Example Catchment		Depth [mm]					
Area = 2000.0 km^2		2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021
Total In		926.7	819.2	1125.8	878.4	979.4	1072.3
Precipitation	**Water In**	900.0	800.0	1100.0	850.0	950.0	1050.0
Inflows		26.7	19.2	25.8	28.4	29.4	22.3
$Q_{in\ SW}$		0.0	0.0	0.0	0.0	0.0	0.0
$Q_{in\ GW}$		-	-	-	-	-	-
$Q_{in\ Transfers}$		26.7	19.2	25.8	28.4	29.4	22.3
Total Out		835.5	801.8	1042.0	842.7	913.6	974.3
Total Evaporation (ET)	**Water Out**	731.0	646.6	818.3	683.2	753.9	776.8
Landscape ET		716.1	632.7	803.3	668.2	739.5	764.0
Incremental ET		14.9	13.9	15.0	15.0	14.4	12.8
Outflows		104.5	155.2	223.7	159.5	159.7	197.5
$Q_{out\ SW}$		76.1	128.8	194.5	130.5	129.7	168.0
$Q_{out\ GW}$		-	-	-	-	-	-
$Q_{out\ Transfers}$		28.4	26.4	29.2	29.0	30.0	29.5
Accessibility: Reserved outflows		28.4	26.4	29.2	29.0	30.0	29.5
Accessibility: Utilizable outflow:		76.1	128.8	194.5	130.5	129.7	168.0
Total Change in Storage		-91.2	-17.4	-83.9	-35.7	-65.9	-98.0
$DS_{f\ SW}$	**Change In Storage**	-66.5	-41.3	-70.6	-52.2	-58.2	-71.6
$DS_{f\ SoilM}$		-23.5	22.9	-9.1	8.5	-7.1	-24.7
$DS_{f\ GW}$		-1.2	1.0	-4.2	8.0	-0.6	-1.7

Time series add context: wetter vs drier years

Evaporation loss resulting from blue water use

Committed vs available outflows

Catchment Flows – Land Cover Detail

*** Single accounting time period**

4 Tier-1 land cover classes

Example Catchment	Natural or semi-natural		Cultivated		Built-up		Waterbodies	
Area	$[km^2]$	%	$[km^2]$	%	$[km^2]$	%	$[km^2]$	%
	908.2	45.4	669.3	33.5	357.6	17.9	64.9	3.2
Water resource details 2020-2021	Depth [mm]	%	Depth [mm]	%	Depth [mm]	%	Depth [mm]	%
Total In								
Precipitation	466.3	44.4	362.0	34.5	189.1	18.0	32.7	3.1
Total Out								
Total Evaporation (ET)	380.8	49.0	298.0	38.4	73.2	9.4	24.8	3.2
Landscape ET	380.8	49.8	296.7	38.8	61.7	8.1	24.8	3.2
Incremental ET	0.0	0.0	1.3	10.2	11.5	89.8	0.0	0.0
Interception ET	100.9	57.4	58.6	33.3	15.4	8.8	1.0	0.6
Transpiration ET	165.4	43.4	184.0	48.3	28.6	7.5	3.0	0.8
Soil Water ET	114.4	58.6	55.0	28.2	24.7	12.7	1.1	0.6
Open Water ET	0.0	0.0	0.3	1.4	4.5	18.4	19.7	80.2
Total Change In Storage	-15.4	15.7	-9.1	9.3	-73.8	75.4	0.3	-0.3
$DS_{f\ SW}$	-0.7	0.7	-0.4	0.4	-71.0	72.5	0.5	-0.5
$DS_{f\ SoilM}$	-13.7	14.0	-8.8	9.0	-1.9	2.0	-0.2	0.2
$DS_{f\ GW}$	-0.9	1.0	0.2	-0.2	-0.9	0.9	0.0	0.0
Internal Flows	0.0		0.0		0.0		0.0	
Interception	101.6	57.3	59.1	33.3	15.6	8.8	1.0	0.6
Surface Runoff	39.0	35.1	21.7	19.6	38.6	34.7	11.7	10.6
Infiltration	325.7	47.8	282.6	41.5	72.3	10.6	1.2	0.2
Pot. GW Recharge	32.0	38.2	34.8	41.5	17.0	20.3	-	-
Baseflow	31.0	36.8	32.9	39.0	19.3	22.9	1.1	1.3
Irrigation	0.0		1.5	100.0	-	-	0.0	

Area – extent of development

Rain – in proportion to area

Evaporation
- Cultivation higher proportion
- Built-up lower proportion

Evaporation – by type

Internal catchment flows
- Impact of land cover
- Used in indicators

Catchment Flows – Land Cover Change Impact

Example Catchment	Actual Land Cover		Reference		Difference
	Depth	%	Depth	%	%
2020-2021	[mm]		[mm]		
Total In	1072.3		1050.0		2.1
Precipitation	1050.0	97.9	1050.0	100.0	0.0
Inflows	22.3	2.1	0.0		
$Q_{in\ SW}$	0.0	0.0	0.0	0.0	0.0
$Q_{in\ GW}$	-	-	-	-	-
$Q_{in\ Transfers}$	22.3	2.1	0.0	0.0	0.0
Total Out	974.3		1020.7		-4.5
Total Evaporation (ET)	776.8	79.7	842.7	82.6	-7.8
Landscape ET	764.0	98.3	842.7	100.0	-9.3
Incremental ET	12.8	1.7	-	-	-
Interception ET	176.0	22.7	230.3	27.3	-23.6
Transpiration ET	381.0	49.0	345.2	41.0	10.4
Soil Water ET	195.3	25.1	264.8	31.4	-26.2
Open Water ET	24.5	3.2	2.4	0.3	919.9
Outflows	197.5	20.3	178.0	17.4	11.0
$Q_{out\ SW}$	168.0	17.2	178.0	18.3	-5.6
$Q_{out\ GW}$	-	-	-	-	-
$Q_{out\ Transfers}$	29.5	3.0	0.0	0.0	0.0
Total Change In Storage	-98.0		-29.3		
$DS_{f\ SW}$	-71.6	73.1	-1.5	5.2	0.0
$DS_{f\ SoilM}$	-24.7	25.2	-27.8	95.0	0.0
$DS_{f\ GW}$	-1.7	1.7	0.1	-0.2	-2492.7
Internal Flows	0.0		0.0		
Interception	177.2		231.8		-23.5
Surface Runoff	111.1		125.3		-11.3
Infiltration	681.8		692.5		-1.6
Pot. GW Recharge	83.9		58.6		43.2
Baseflow	84.4		58.6		44.0
Irrigation	1.5		0.0		

Water imported ↑

Less evaporation ↓

Water exported ↑

More storage ↑

Less surface runoff ↓

More baseflow ↑

Modelling approach enables quantification of:
- Impact of current land cover
- Impact of future land cover

Challenges perceptions

Where can changes be made to improve water security?

Catchment Flows – Managed Flows

Only a small proportion of precipitation becomes available as internal water resources

Demand management will be increasingly important

Example Catchment	Depth [mm]					
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Total Demand	30.9	28.6	30.8	31.0	30.3	28.1
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Built-up	10.6	9.7	10.3	10.3	10.6	9.6
Total Returned	15.1	13.9	15.1	14.8	15.1	14.6
Cultivated	-	-	-	-	-	-
Built-up	15.1	13.9	15.1	14.8	15.1	14.6
Deficit	0.3	0.3	0.2	0.7	0.3	0.1

Withdrawals mainly for urban water supply in this catchment

Returns from urban users can be reused

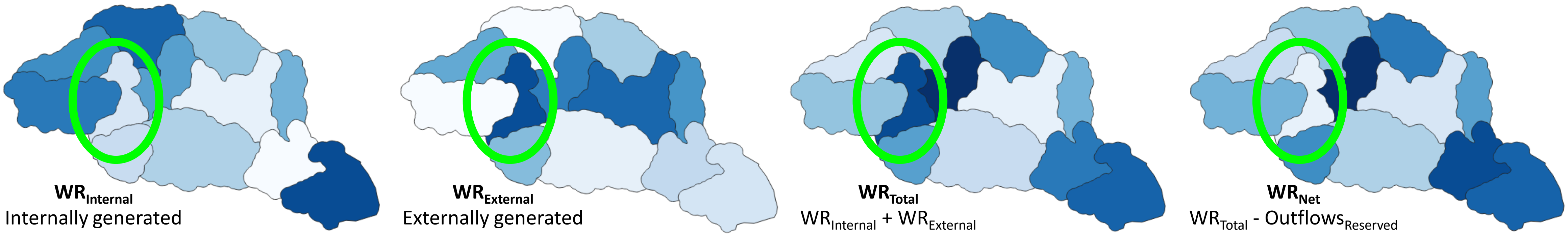
Indicators

Indicators are important for summarising information

- Water resource accounts used in calculating SEEA-Water indicators
- Useful to differentiate between internal and external water resources
- Finer spatial resolution enables mapping spatial variability
- Water depths enable comparison between catchments

More

Less



$WR_{Internal}$
Internally generated

$WR_{External}$
Externally generated

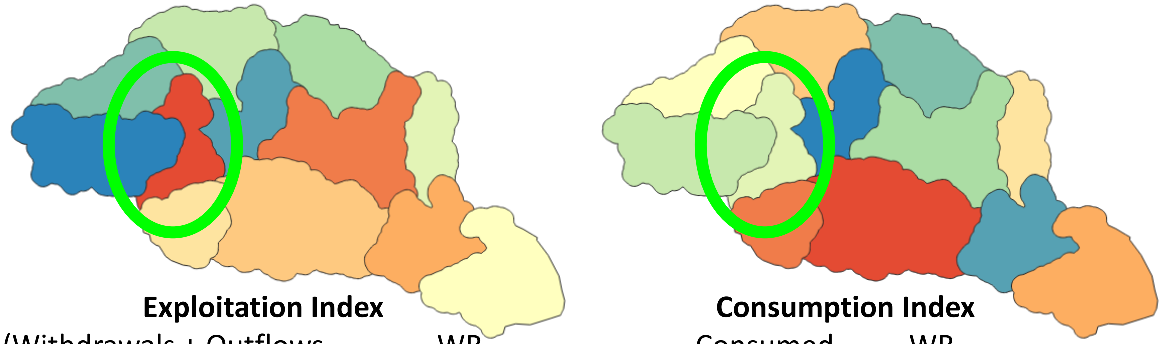
WR_{Total}
$WR_{Internal} + WR_{External}$

WR_{Net}
WR_{Total} - $Outflows_{Reserved}$

High

Medium

Low



Exploitation Index
$(Withdrawals + Outflows_{Reserved}) / WR_{Total}$

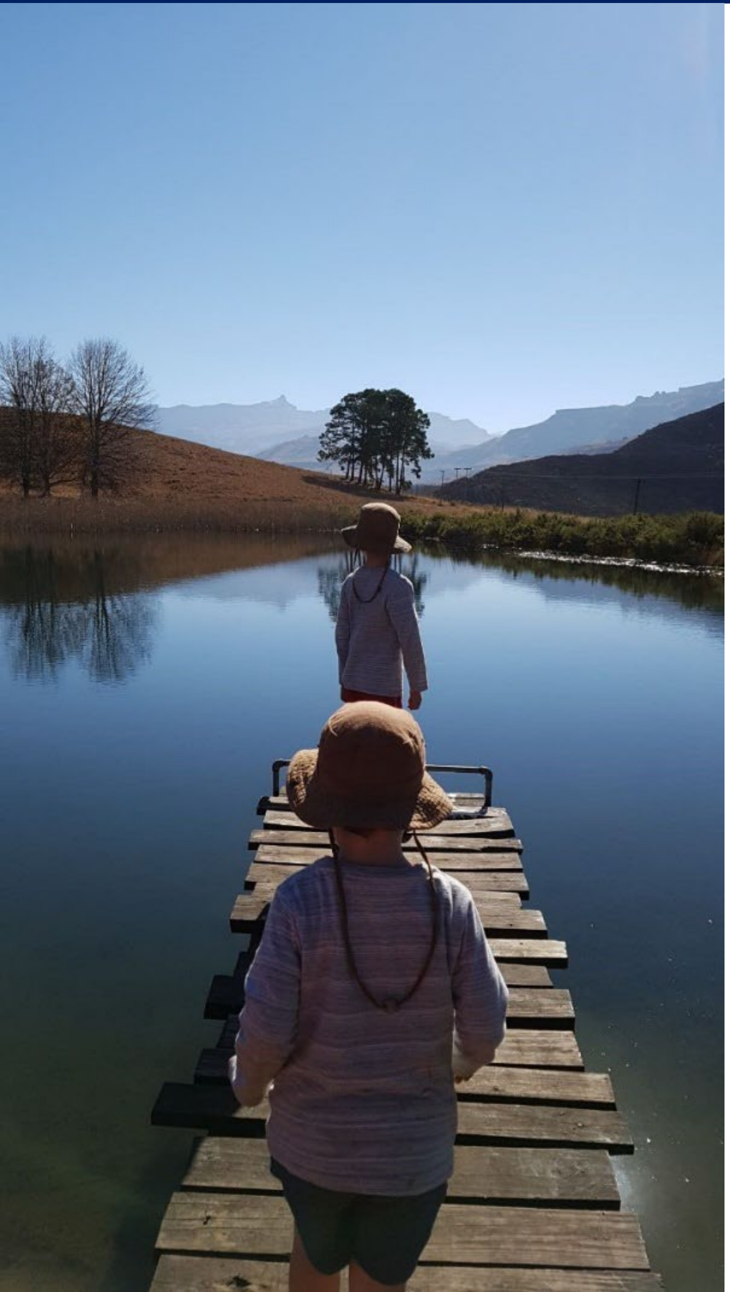
Consumption Index
$Consumed_{Total}) / WR_{Total}$

Conclusions

Different but complementary view to NWA

- Finer scale (can be spatially aggregated)
    - More local context
    - Understand spatial variability
- More detailed and holistic catchment level view
- Physical accounts of water quantity
- Support land and water management decisions
- Help in understanding interlinkages between land, water and ecosystems

The Way Forward



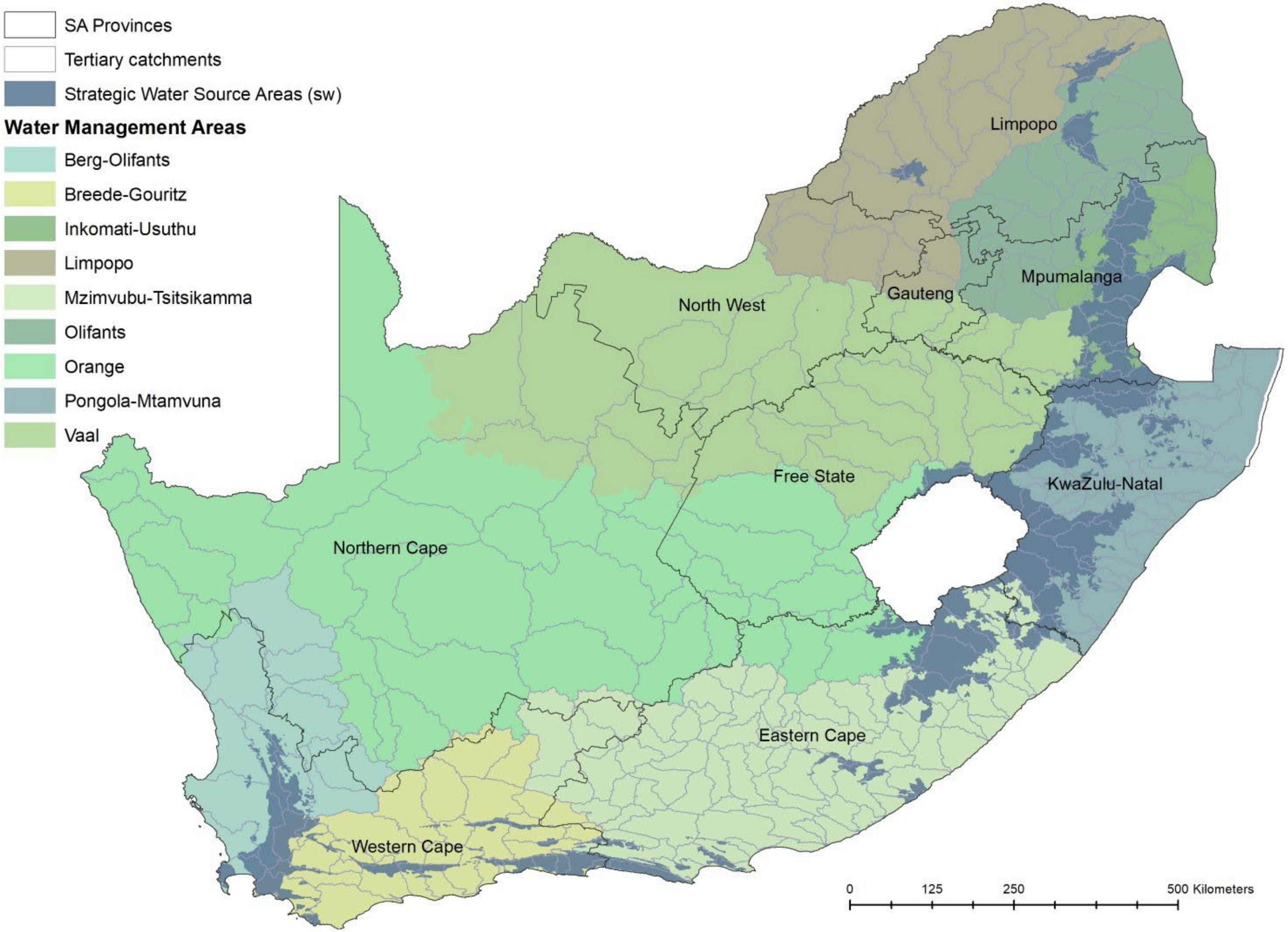
Vision

Annual water resource accounts, compiled for the whole country, every year, at a range of catchment scales

Next steps

- Compile accounts for whole country
- High level discussion regarding data access and institutional ownership of the accounts and their production
- Capacity building among stakeholders regarding potential value and application of information in the accounts

Administrative and Natural Accounting Areas



Questions

Administrative and natural accounting areas

- How do other countries deal with the mismatch between catchments and administrative boundaries for water management and water accounting?
- What recommendations do you have for managing these mismatches to enable the water resource accounts to best complement SEEA-Water and other natural capital accounts based on SEEA?

Modelling approach

- Is a modelling approach acceptable, considering data constraints and the implications when making interlinkages with other natural capital accounts?
- What level of detail and accuracy is appropriate to provide modelled water resource accounts for a whole country without excessive effort?

Interlinkages with other NCA

- What interlinkages can be made with other natural capital accounts to provide better information for management of water resources and landscapes, and also for the policies that guide management of resources?